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Manufacturing of PMMA Cam Shaft by Rapid Prototyping

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Abstract

Rapid prototyping is a technique used to quickly fabricate an assembly, components or parts using three-dimensional Computer Aided Design and Computer Aided Manufacturing (CAD-CAM). It is an additive layer manufacturing technology. Cam shaft is a component in which a set of cams becomes an integral part to a shaft placed in its respective positions and directions according to the application of the particular cam shaft. These cam shafts are used in many industries especially in automobile, aerospace and marine industries. They are used in the engines of any automotive.

In the engines these cam shafts are used for operating the inlet valves and outlet valves. These cam shafts are to be precisely manufactured in order to avoid the timing errors in opening and closing of the ports. So these camshafts are mostly machined and manufactured by computer operated machine systems. In these systems the various process of machining are listed and arranged in a specific order and connected to a computer. So the raw material undergoes several processes in several machines during the manufacture and finally the cam shaft is obtained. The main advantage of this type of manufacturing is that more number of precise components is obtained.

Rapid prototyping process is one of the newly emerging manufacturing processes that could be used to manufacture cam shaft precisely. Rapid prototyping uses the process additive manufacturing in which the molten raw material is added layer by layer. The major problem in the rapid prototyping process is inability to use metals. But there are somematerials that possess the properties of metals and also have the ability to be used in rapid prototyping process. The material which is best suited for camshaft manufacturing using rapid prototyping was poly (methyl methacrylate) (PMMA).Using this method of manufacturing process the space required and the cost required for manufacturing can be reduced. Performanceof the conventionally manufactured cam shaft and cam shaft manufactured by rapid prototyping can be compared and analysed.

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1.1. Introduction

Rapid Prototyping is a process which is used to create a prototyping of a newly created design in order to carry out further advancement or changes in the design. Rapid Prototyping is a material addition process which makes use of additive manufacturing technology in which the component is produced by adding the material layer by layer in the form of powder with the advancement in additive manufacturing technology, the process used to produce only prototypes can be used in mass production for producing the components directly. Camshaft, which is produced by conventional and other unconventional machining processes, requires a series of processes to obtain the final product which requires a lot of power, space, cost and time. In thisit is proposed to produce the camshaft by an additive manufacturing process using Rapid prototypes**. [4]**

1.2. Definition

RP is an additive manufacturing process in which a three dimensional product or component is produced from a three dimensional design using computer aided design (CAD) software in a very short period of time. The components are produced by metal deposition or plastic process. One or more materials can also be added layer by layer in a plane. The 3-Dimentional models are created by various CAD software's and the 3D model is then fed into the Rapid Prototyping machine. It is fed in .STL format so that the RP m/c reads it.

1.3. Types

Rapid prototyping is mainly classified in 4 types.

(a) Stereo lithography (SL)
(b) Selective laser sintering (SLR)
(c) Fused deposition modelling (FDM)
(d) Laminated object sintering (LMS)

1.3.1 Stereo lithography (SL)

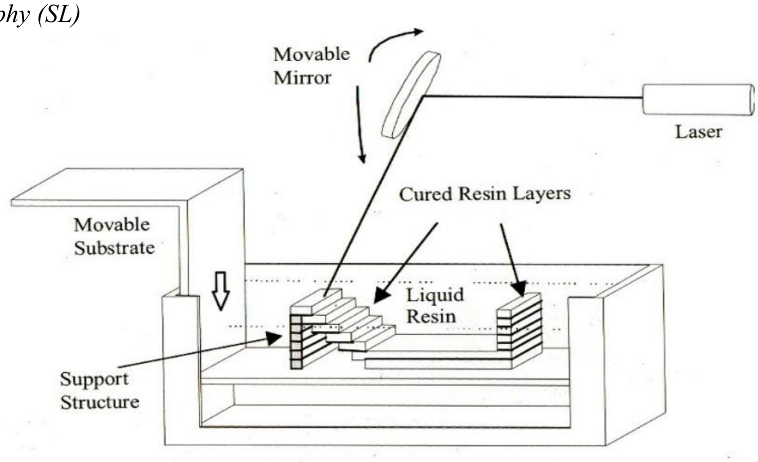

Fig 1 Stereo lithography (SL) [2]

In the advanced stereo lithographic systems a blade spreads resin on the part of the material as the blade travels through the vat.This process helps in obtaining a reduced recoating time, smoother surface and reduced trapped volumes. After the part is deposited the block is removed from the vat and excess resin is drained. It will take a long time because of the high viscosity of liquid resin. The part obtained will be in green color and is then post-cured in an ultra violet oven after removing support materials. [2]

1.3.2Selective Laser Sintering (SLR)

It is a metal addition process that uses 3 Dimensional printing technology in which the power source is a laser which directs the laser beam on the points defined by the designed Computer Aided Design model to sinter the powdered material and binds the material to form the final product. In the Selective Laser Sintering process a fine polymeric powder is spread on the substrate with a help of a roller. Before the process starts the entire bed's temperature is raised just below the melting point by infrared heating.

This reduces the thermal distortion and facilitates the fusion to the previous layers. The laser is modulated in a way that the grains that are in contact with the beam are only affected. Then the process starts and the laser scanning cures a slice and the bed is lowered, so that the powder fed chamber is raised and covers with the powder. By the counter rotating roller the powder is spread evenly over the build area. The main advantage of this process is the support structures are not required because of the unsintered powder acts as a support structure. And this powder can be cleaned away and it also can be recycled after the model is completed.Fig 2.Shows a detailed schematic diagram of Selective Laser Sintering Process (SLS) [3], [2]

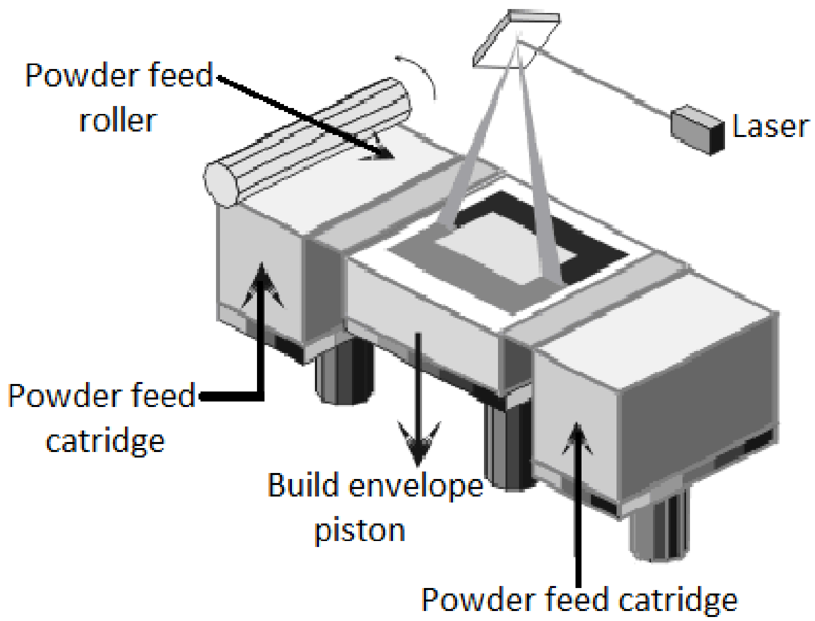

Fig 2. Selective Laser Sintering (SLS) [2]

1.3.3 Fused Deposition Modelling (FDM)

In this method, material is laid down in layers and the material is supplied by plastic filament or a metallic wire. In Fused Deposition Modelling a movable nozzle which has only X-Y movement deposits a molten polymeric material on to a substrate. The material is heated slightly above its melting temperature. It is chosen in order to get it solidified within a very short period of time after extension and cold-welds to the last formed layer. The modern Fused Deposition Modelling process involves two nozzles, one for the part material and the other for additional material. The support material is of poor quality and it can be broken easily. In more advanced process water-soluble support structure material is used. The additional structure can be deposited with fewer density by providing gaps between the consecutive roads. Fig3. Shows a detailed schematic diagram of fused deposition modelling process (FDM)

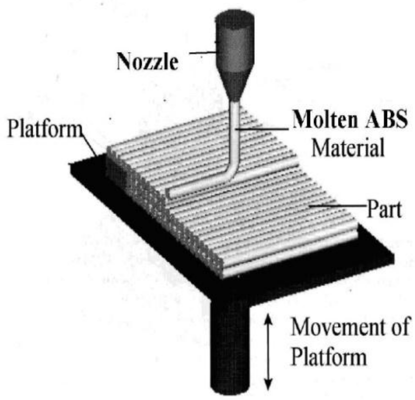

Fig 3 Fused Deposition Modelling (FDM) [2]

1.3.4 Laminated Object Manufacturing (LOM)

In this method layer of adhesive coated material is in turn glued out to obtain the component's shape using laser or a knife. In Laminated Object Manufacturing process the slices are being cut in required shapes from roll of material by using a laser beam. The new slice is bonded to the previous slice with the help of a hot roller which applies a heat sensitive adhesive. The wanted material is also hatched in rectangles for later removal. If one slice is completed, the platform can be lowered and the roll of the material can be advanced by winding this onto a roller until a new area of sheet lies over the part. After the process is completed they are sealed to prevent laser distortion of the prototype through the absorption of water. This process is 5-10 times faster than other rapid prototyping process. The limitation of this process is undercuts and re-entrant features cannot be made. [2]. Fig. 4 shows a detailed illustration of Laminated Object Manufacturing process

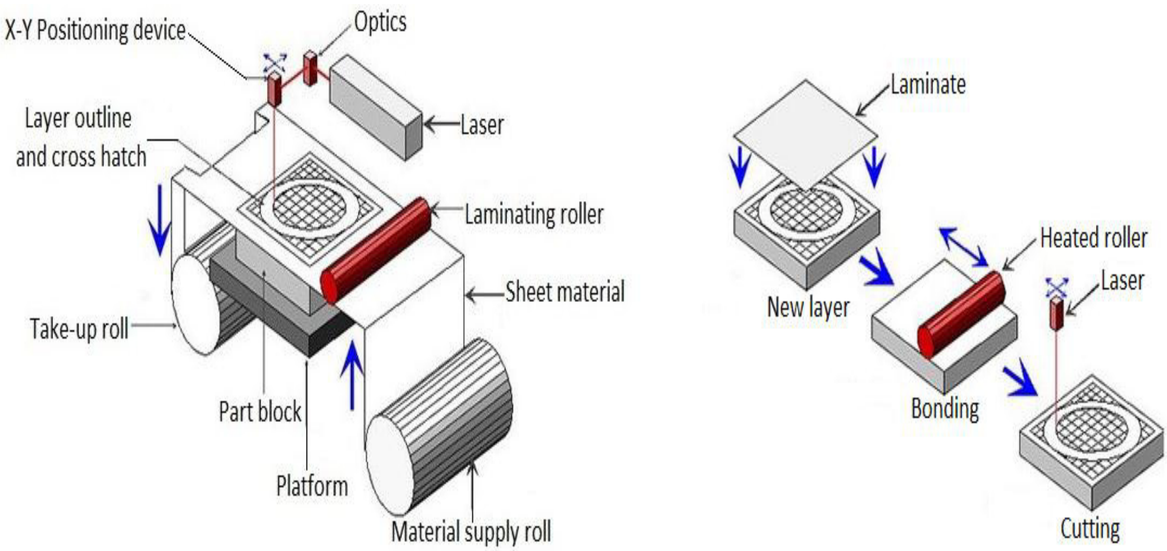

Fig 4 Laminated Object Manufacturing (LOM) [2]

1.4 Cam shaft production.

The method that favour the production of cam shafts are

(i) Stereo Lithography

(ii) Fused Deposition Modelling

These two methods are selected because this process manufactures the component faster and in a simple manner. And these two processes can be involved in mass production with few changes in the machine. Among these two processes Stereo Lithography is selected because there is no need of support material and also waste powder material can be reused and it is most suitable for mass production and faster compared to FDM. [1]

The cam shaft to be manufactured is modelled in a suitable cad software is shown in the figure 5.

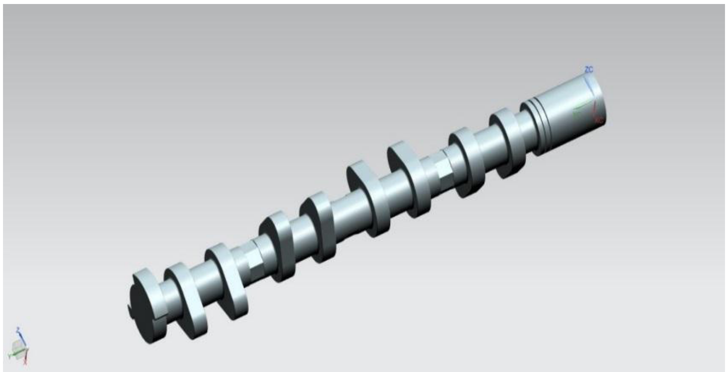

Fig 5model of a cam shaft developed in a cad software for RP production

1.5 Modification to be done to Selective Laser Sintering Machine

In this process all the layers can be added in a single setup but in order to adapt to mass production for increased production process, it is carried out into a step by step process on a moving platform. Each layer is added by a different setup. This by implementing a layer by layer additive process, the output of the manufacturing process could be enhanced. This is explained in the figure 6, 7, 8, 9, 10, 11and 12.

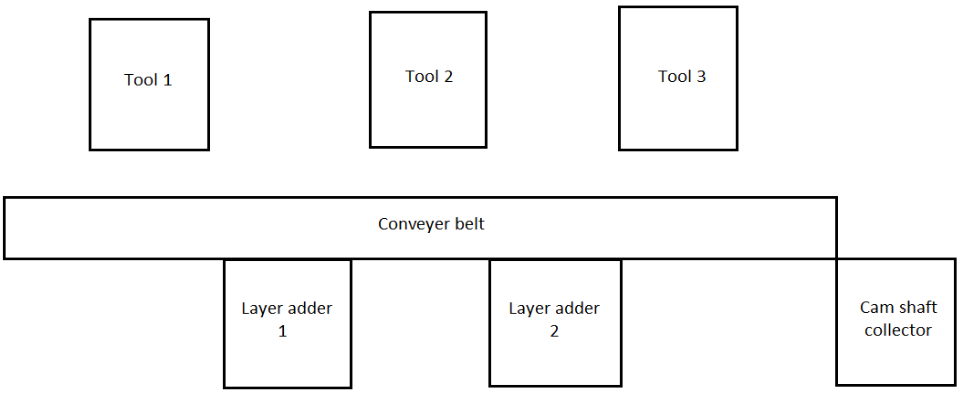

Fig 6 explaining the modification done in RP process

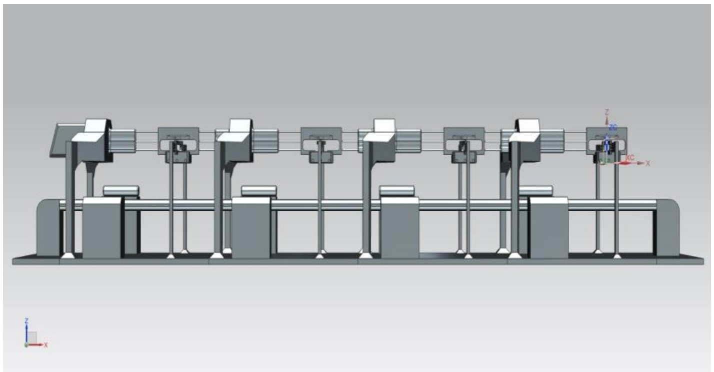

Fig 7 showing the side view of the modified RP machine

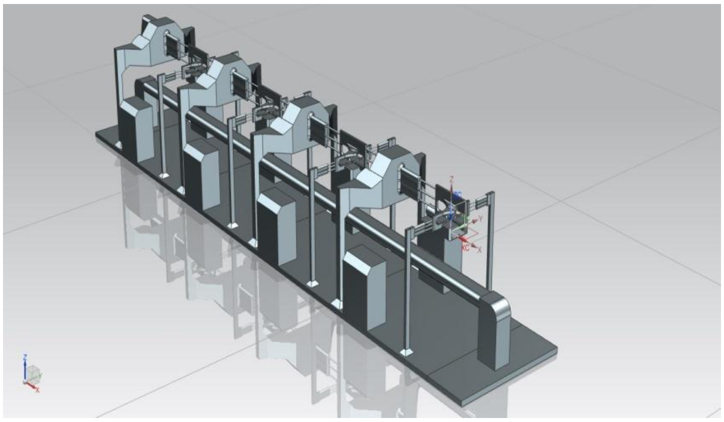

Fig 8 showing the 3 dimensional representation the modified RP machine

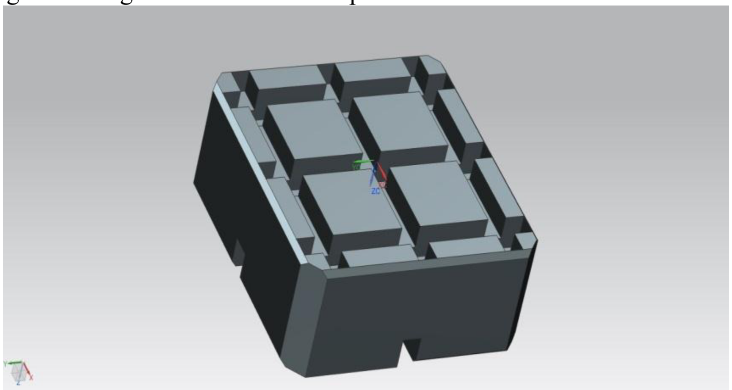

Fig 9 showing the tool holder which is provided with paths for the movement of the laser tool

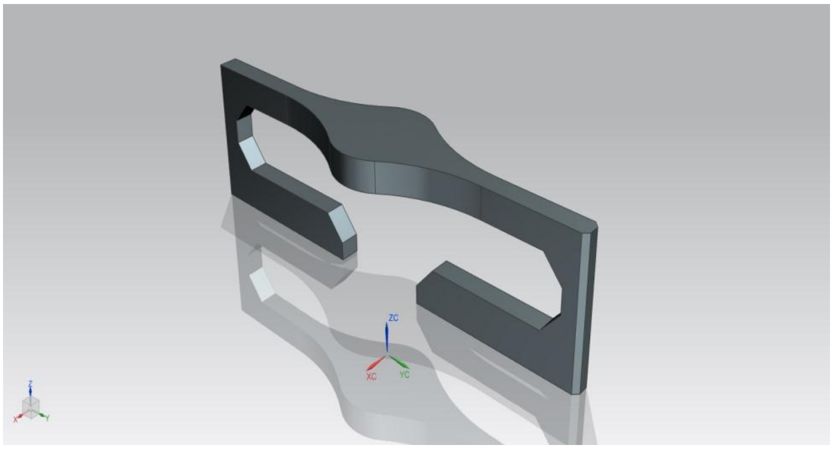

Fig 10 showing the arm which moves the tool holder in x and y axis direction

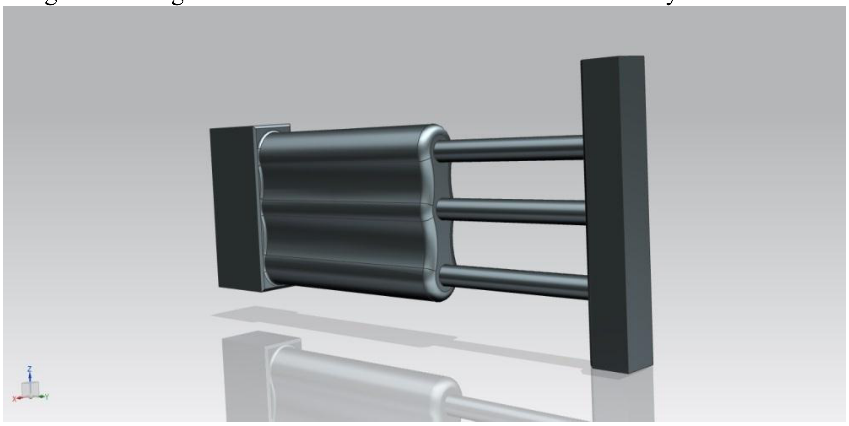

Fig 11 shows the hydraulic cylinder with pistons for the movement of the arm

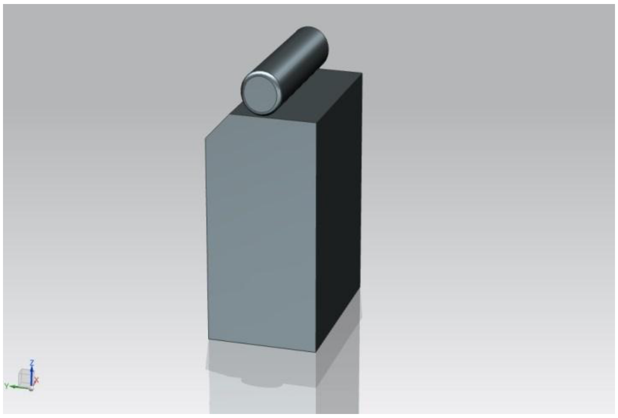

Fig 12 showing the layer feeder with leveling roller

1.6 Improvements.

In order to increase the thickness of each layer added or in other words, to increase the amount of material added, the strength or power of laser beam has to be increased. By increasing the power of the laser, the amount of material to be added is increased which in turn reduces the production time as well as number of stages of layers In order to reduce the time taken for sintering process the number of laser tools or laser beams can be increased. This allows us to increase the number of Cams in a single layer so that an increased number of cam shafts can be produced which increased productivity. The time taken at each stage has to be divided equally among every stage in order to avoid time lag so the system is synchronized among all stages. Figure 13 and 14 explains the process.

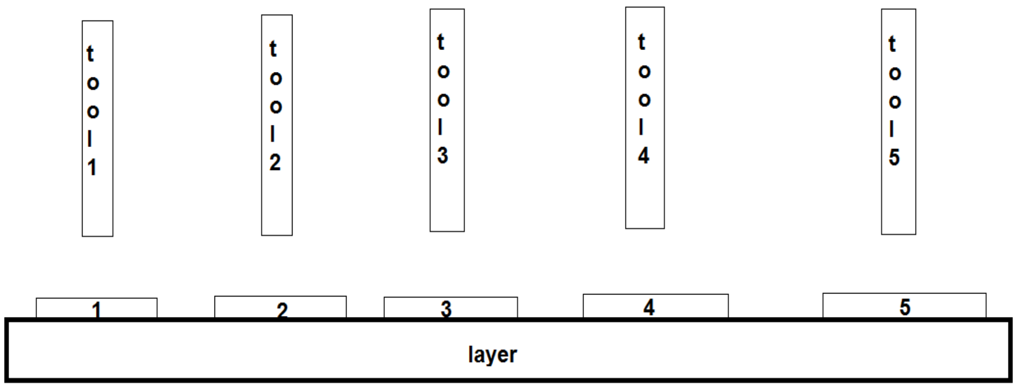

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Fig 13 explaining the multiple tools used for manufacturing multiple cams.
In fig 14, 15, 16, 17, 18 represents the layout of the cams

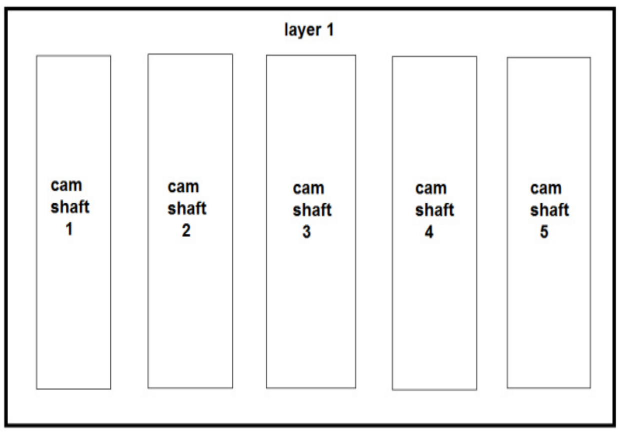

Fig 14. Showing the layout of multiple cams in a single layer

1.7 Material Selection

The process which is used for the manufacturing of cam shaft is decided and alterations are made in it. But the material which is to be used for the production cam shaft is also an important factor. Under deep analysis of various polymer materials we have selected poly (methyl methacrylate) PMMA as a material to be used for the production of cam shaft under modified selective laser sintering method instead of the conventionally used cast iron

Table1. Comparison of properties between poly methyl methacrylate and cast iron

property	symbol	unit	Poly methyl methacrylate	Cast iron
Young's modulus	E	GPa	2	83
Yield Strength	σ_y	MPa	70	45
Ultimate strength	σ_u	MPa	344	66.16
Percentage elongation [=% strain at failure]	%EL	-	0.9691	2.47
Glass transition temperature	T_g	^{o}c	105	-
Ceiling Temperature	T_c	^{o}c	220-230	-
Critical weight	m_c	-	27500	-
Entanglement Weight	-	D_a	5900-7900	-
Water Absorption	%	-	2.0	-
Modulus of elasticity	E	GP_a	3.3	-
Sheer Modulus	G	GP_a	1.7	-
Poisson's ratio	V	-	0.38-0.40	-
Density	P	g/cm^3	1.190 at 20^oc	-
Tensile strength	σ_y	MP_a	70	-
Critical Strain	%	-	0.8-1.30	-

1.8 Advantages

By implementing the above mentioned solutions we will be able to gain the following advantages over conventional machining process

(a) Increased productivity
(b) Less time
(c) Less space
(d) No wastage of the materials

2. Conclusion

Thus, the Rapid Prototyping metal addition 3-D printing process of SLS can be adapted for mass production of complex parts. The advancement in SLS technology enables the increase in production rate. The advancements made in the setup consist of increasing the number of platforms and the number of laser points to be directed onto the material. This allows multiple cams to be produced at a time by the help of a powerful laser. Thus, this helps in mass production of the component.

3. References

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